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Mechanical Properties of Bamboo Fibre Reinforced Concrete

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Abstract: Concrete is one of the most widely used materials in the construction sector since its materials are easily accessible and can fit any structural shape. However, plain concrete's characteristics are not very durable caused of its high amount of cracking or pore structure. The objective of this study is to characterise the physical properties of bamboo fibre, to determine the mechanical properties of bamboo fibre reinforced concrete and lastly to determine the optimum percentage of bamboo fibre reinforced concrete. Therefore, 0.00 %, 0.50 %, 1.00 % and 1.50 % of bamboo fibre was used in this study with 30mm length of bamboo fibre and the majority of the procedure was followed the British Standard (BS) method. The experimental work consists of the testing slump, concrete density, water absorption, compressive strength, tensile strength, flexural strength and ultrasonic pulse velocity (UPV). Based on the result obtained, concrete containing bamboo fibre cannot significantly improve the strength of reinforced concrete and the characteristics of bamboo fibre that absorb more water was affected the slump result and causes of occurring honeycomb and 30 N/mm^2 concrete strength are not achieved. It means that result for plain concrete achieved the highest result compared to another sample with mix proportion of bamboo fibre. Therefore, the uses of bamboo fibre in concrete are not suitable since the characteristics that absorb water and bamboo fibre is commonly used in the textile industry and polymer composite products.

Keywords: Fibre, Bamboo Fibre, Concrete, Strength

1. Introduction

Concrete is the most frequently used of construction material worldwide. However, plain concrete's characteristics are not very durable. There are lots of factors can be contributing to the deterioration or loss of durability of concrete structures. The most common is a high amount of cracking or pore structure. Most of concrete structure in constructions industries have many cracks. Larger cracks allow such substances' access to the steel, hence increasing corrosion. The fact that concrete materials have a low tensile strength as compared to their compressive strength has long been recognized. Due to the natural weakness of concrete in tension, it has been used as a compressive member material in the

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majority of concrete constructions. Even if static tensile stress are avoided on concrete members, it is difficult to isolate them from dynamic tensile stresses [1]. Because plain concrete has a low tensile strength, it causes brittle of concrete. Fundamentally, this mechanical property of concrete (like with any other building material) is based upon the collaborative contribution of its three constituents: water, cement, and aggregate. Because concrete is classified a quasi-brittle material, it is important to consider not only tensile strength but also tensile toughness while studying its cracking behavior [2].

Therefore, the reinforcement bar are required to overcome the tensile stress [3]. Not only that, the negative impact as mention above can be control with the new materials that has a unique characteristic [4]. For example, natural fibre, steel fibre, synthetic fibre or glass fibre. Physical properties of natural fibre such as bamboo fibre can help by controlling the concrete crack and increase the tensile strength of concrete while reducing the possibility of brittleness. Not only that, based on the physical properties of bamboo fibre, the flexural strength also can increase according to the increasing the tensile strength. However, in Malaysia, there are many natural resources according to equator climate such as wood, coconut, oil palm and especially bamboo. But, the resources and application of bamboo in civil engineering is very limited. There are commonly applied for textile and furniture since there are many professional manufacturer and high demand on this field. Thus, with this study, it can solve and improve the strength of concrete as well as expand the use of bamboo in Malaysia. At once it can focus toward sustainable development by applying alternative material for their efficacy in construction.

Bamboo fibres are natural fibres that produced from the bamboo tree that commonly grows in tropical and subtropical countries area such as China and Malaysia [5]. Bamboo Gigantochloa Scortechinii (Buluh semantan) is a very popular in Malaysia according to the most resources bamboo found in Malaysia. Especially in Peninsular Malaysia [6]. Bamboo is also extremely sturdy due to the strong fibre bundles in its longitudinal direction [7][8]. When bamboo fibres are used in reinforced concrete fibres, they show a great potential and increased the strength, allowing them to withstand more load than conventional concrete, effectively acting as a crack resistor. Due to its great elasticity, it is a very valuable construction material in locations where has a big risk of earthquakes [9][10]. Due to its special features, including a low weight-to-strength ratio, high tensile strength, and considerations such as the high cylindrical form of its Maxwell strength. Besides that, bamboo is characterized as having a low cost, easy to get, and a high strength comparable to steel. Furthermore, bamboo is an environmentally friendly, fast-growing, and renewable resource material that can be plant and matured in as little as 3-5 years [11]. Additionally, compare to synthetic fibres such as glass or steel, bamboo and bamboo fibres have low manufacturing costs. Bamboo has consistently attracted the interest of scientists and engineers in the construction industries and as a building material to use as a reinforcement member in concrete mixtures [10].

1.1 Objective

The aim of this study is to learn more about effect of bamboo fibre in concrete strength and an improvement on concrete. The main objective of this study are:

- To identify the physical properties of bamboo fibre
- To determine the mechanical properties of bamboo fibre reinforced concrete.
- To determine optimum percentage of bamboo fibre reinforced concrete.

1.2 Scope of Study

The scope of this study is to achieve the objective and it is primarily focused on experimental work. This study is to investigate the strength properties of reinforced concrete that containing bamboo fibres. The British Standard (BS) are used in this study to define testing methods and procedures. The following is the study's scope:

i. The specimens that are used is cube, cylinder and beam for each batch with size (100 mm x 100 mm x 100 mm), (150 mm diameter x 300 mm height) and (500 mm x 100 mm x 100 mm) respectively.
ii. Cement grade that will be used is M30.
iii. In this study, the type of fibre used is bamboo fibre with 30.00 mm length and 0.02 mm diameter.
iv. The volume fraction of bamboo fibre that will used in this study is 0.00 %, 0.50 %, 1.00 %, 1.50 %.
v. The test that will be carried out are slump, concrete density, water absorption, compressive strength, split tensile strength, flexural strength test and ultrasonic pulse velocity (UPV) test.
vi. To know the effect of bamboo fibre on the performances of bamboo fibre reinforced concrete beam compared to plain concrete, the structural performance of beams is calculated by using a slump, concrete density, water absorption, compressive strength, split tensile strength, flexural strength test and ultrasonic pulse velocity (UPV) test

2. Materials Used

2.1 Cement

The Cement is most widely used in construction industry. In this study, Ordinary Portland Cement (OPC) of CEM I are used according to BS EN 197-1. It is because of its suitable for all general application in construction.

2.2 Coarse Aggregates

Size coarse aggregate can be described as greater than 5.00 mm according to BS 410. Crushed aggregates increase strength because the particle sizes interlock, while rounded aggregates improve flow because internal friction is lower. All of the concrete mixes were used locally available crushed granite aggregate that passing through 10.00 mm and retaining 12.50 mm.

2.3 Fine Aggregates

Aggregate that less than 5.00 mm is described as fine aggregate according to BS 410. Crushed from broken stones and sands can be used in this research. The fine aggregate plays a critical role in reducing separation. All of the concrete mixes were use locally available sand that had passed through a 5.00 mm sieve.

2.4 Superplasticizer

The used of superplasticizer in this study is Sika ViscoCrete-2192 with free chloride according to BS 5075. It is suitable for all type of Portland Cement and SRC (Sulphate Resistant Cement). The recommended uses of superplasticizer in concrete is 500 to 2000 ml per 100 kg of cement or 0.60 % of weight cement. It also depends on workability and strength requirement. In this study, the amount of superplasticizer that was used are by using 0.60 % of weight cement.

2.5 Physical Properties of Bamboo Fibre

The type of bamboo fiber that was used are Semantan bamboo. The physical properties of bamboo fibre containing in concrete is very important and needs to take a consideration. This is because of the properties of bamboo fibre will affect the strength of reinforced concrete. The length of bamboo fibre that was used in this study are 30.00 mm length while the diameter of bamboo fibre is 0.02 mm as shows in Figure 1 and Figure 2 respectively [12].

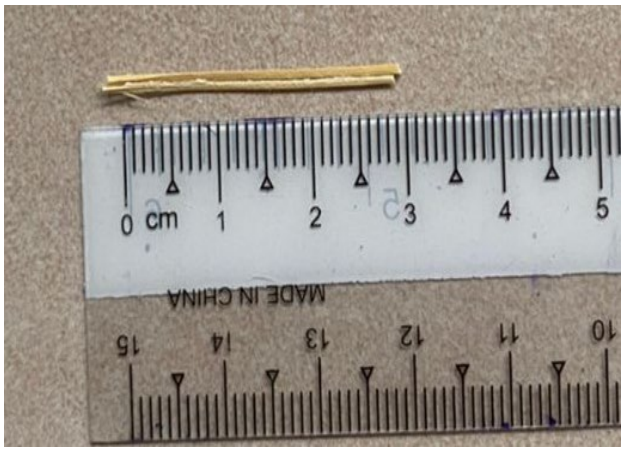

Figure 1: Length of Bamboo Fibre

Figure 2: Diameter of Bamboo Fibre

3. Methodology

3.1 Flow Chart

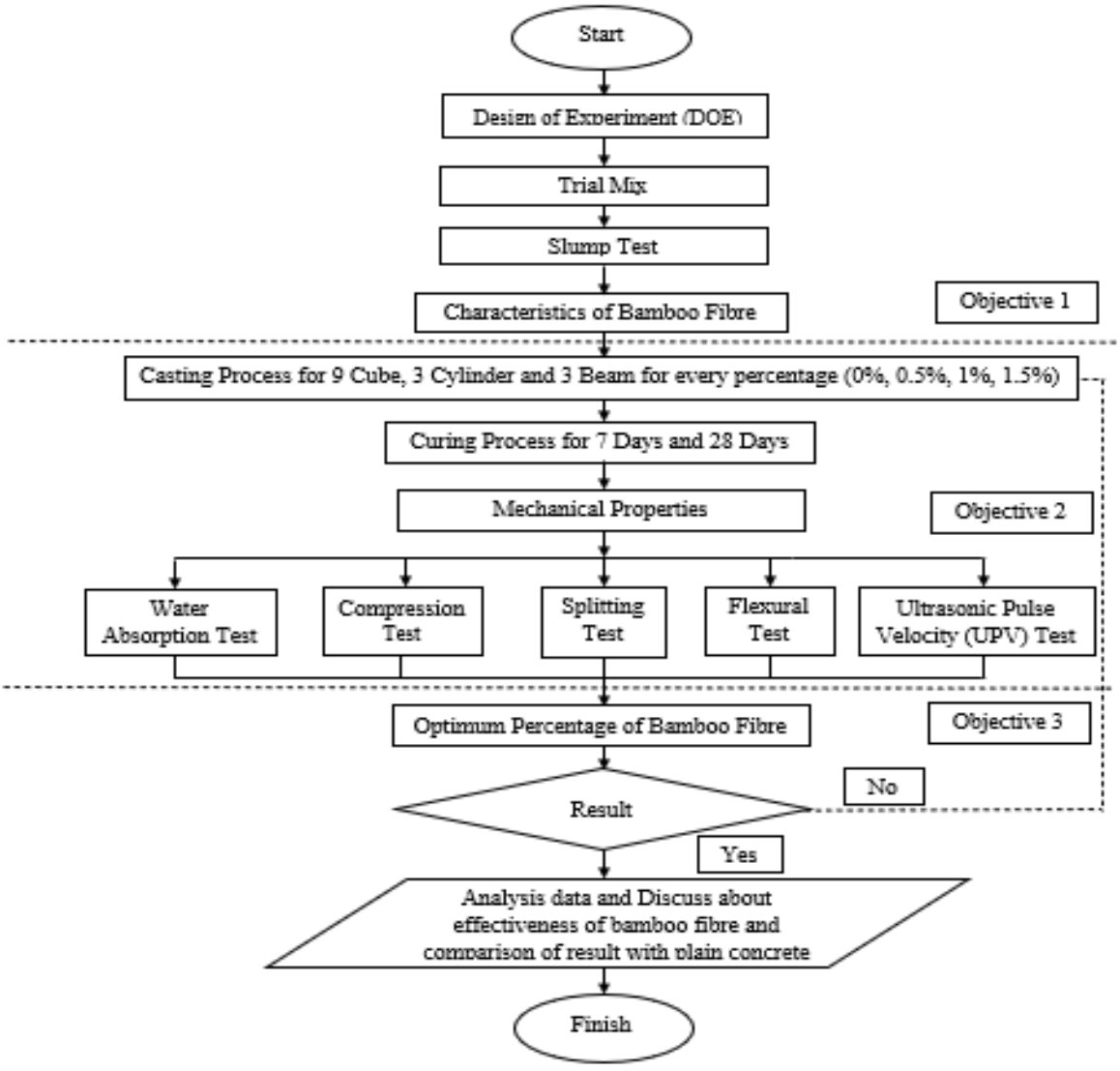

Figure 3: Flow chart of this study

3.2 Mix Design

The ratio mixture between cement, fine aggregate, and coarse aggregate and bamboo fibre is 1:1.89:2.84 according to British Standard (DOE Method). This ratio is design for mildly exposed condition. To make M30 grade concrete, the mix proportions are taken which is the aggregate is 10 to 20 mm sieve scale, the sand is 1.19 mm, and the cement is used Ordinary Portland Cement (OPC). The percentage of bamboo fibre that mixed with concrete is 0.00 %, 0.50 %, 1.00 %, 1.50 % of weight of cement. The size of cube is 100 mm x 100 mm x 100mm while for cylinder and beam size is 150 mm diameter and 300 mm height, 500 mm x 100 mm x 100 mm respectively.

Table 1: Quantities of 9 cube for every batch

Batch	Water (L)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Superplasticizer (L)	Weight of Bamboo Fibre (kg)
0%	2.30	4.18	6.89	10.33	0.2508	-
0.5%	2.30	4.18	6.89	10.33	0.2508	0.0405
1%	2.30	4.18	6.89	10.33	0.2508	0.0810
1.5%	2.30	4.18	6.89	10.33	0.2508	0.1215

Table 2: Quantities of 3 cylinder for every batch

Batch	Water (L)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Superplasticizer (L)	Weight of Bamboo Fibre (kg)
0%	4.60	8.36	13.77	20.66	0.5016	-
0.5%	4.60	8.36	13.77	20.66	0.5016	0.07155
1%	4.60	8.36	13.77	20.66	0.5016	0.14310
1.5%	4.60	8.36	13.77	20.66	0.5016	0.21465

Table 3: Quantities of 3 beam for every batch

Batch	Water (L)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Superplasticizer (L)	Weight of Bamboo Fibre (kg)
0%	4.37	7.94	13.09	19.63	0.4764	-
0.5%	4.37	7.94	13.09	19.63	0.4764	0.0675
1%	4.37	7.94	13.09	19.63	0.4764	0.1350
1.5%	4.37	7.94	13.09	19.63	0.4764	0.2025

4. Results and Discussion

4.1 Slump

Slump test is very important to determine the workability of fresh concrete. In this study, slump test was conducted which is to measure the consistency and workability of concrete when addition of bamboo fibre. Table 4 shows the result slump for cube specimen.

Table 4: Result slump test for cube

Mix Proportion of Bamboo Fibre (%)	Slump Test (mm)
0%	45
0.5%	15
1%	7

1.5%	5

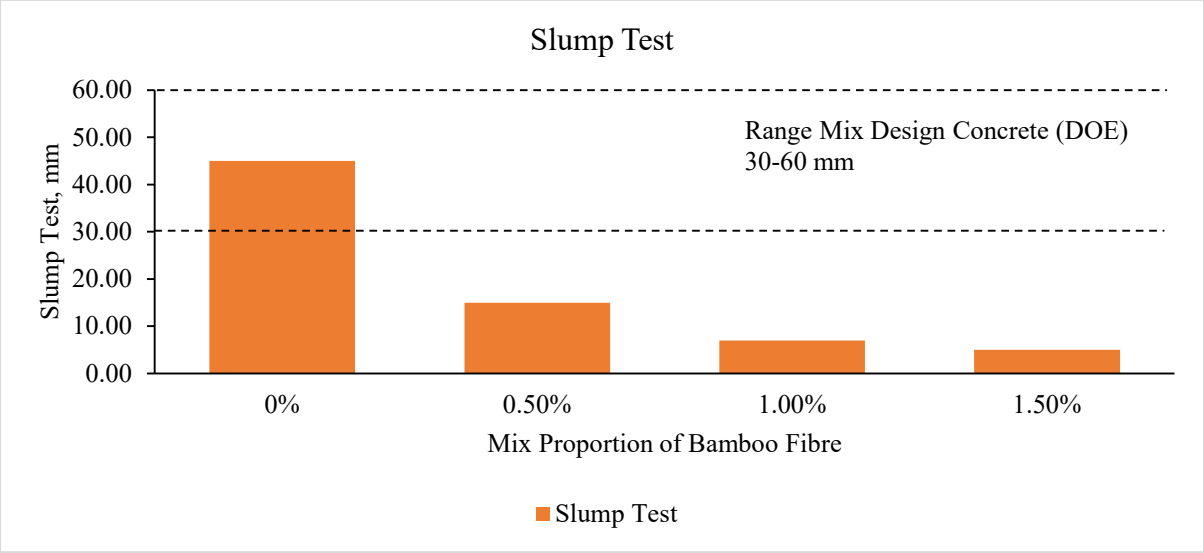

Figure 4: Slump test versus Mix proportion of bamboo fibre.

According to figure 4.1 above, the result of slump test of plain concrete has been achieved the highest value which is 45 mm compared to 1.50 % of bamboo fibre that mixture in concrete which only achieved 5 mm. Besides that, the slump for 0.50 % and 1.50 % of bamboo fibre decrease 30 mm and 38 mm respectively from the highest value. This is because of the bamboo fibre that absorb water during mixing the concrete with bamboo fibre and cause occurring dry concrete. It shows that, slump of plain concrete is better that other mix proportion because of the result obtain still in range of mix design concrete (DOE) which is 30 mm to 60 mm. Based on the graph above, the trend shows constantly decreasing, which is the more addition of bamboo fibre in concrete, the slump result will be decrease. Lastly, the uses of bamboo fibre in concrete are not suitable because of their properties that absorb water.

4.2 Concrete Density

Concrete density was obtained after 7 and 28 days cured in water tank before tested a compressive strength test. The sample was dried by using cloth after removed from water tank before weighed the sample on the weighing balance. The concrete density sample with different percentage of bamboo fibre were recorded in table 4.2 for 7 and 28 days.

Table 5: Result 7 and 28 days concrete density for cube

Mix Proportion of Bamboo Fibre (%)	Concrete Density for 7 days (kg/m^3)	Concrete Density for 28 days (kg/m^3)
0%	2336.67	2380.00
0.5%	2300.00	2303.33
1%	2273.33	2286.67
1.5%	2253.33	2293.33

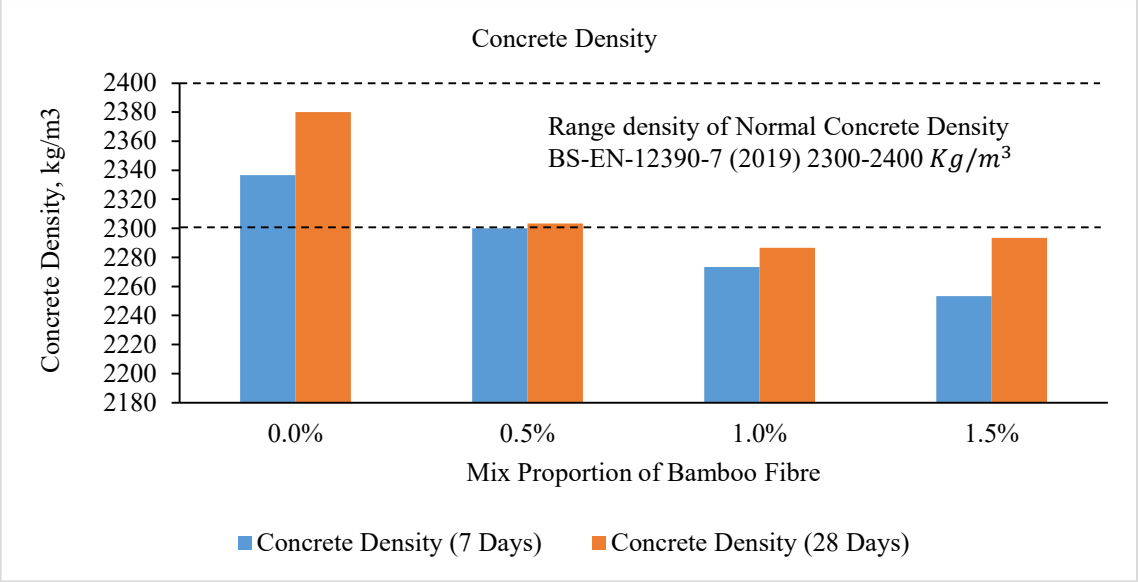

Figure 5: Concrete density versus mix proportion of bamboo fibre for 7 and 28 days

Based on the Figure 5 above, concrete density of cube specimen shows trend decreasing while increasing the percentage of bamboo fibre in cube specimen. According to the graph, the highest concrete density for 7 days was 2336.67 kg/m^3 which is 0.00 % of bamboo fibre mix with concrete while the lowest concrete density for 7 days was 2253.33 kg/m^3 which is 1.50 % of bamboo fibre used in concrete. Furthermore, in 28 days cured in water tank, the concrete density of cube specimen shows 0.00 % of bamboo fibre achieve the highest value which is 2380.00 kg/m^3 compared to 1.00 % of bamboo fibre that achieved the lowest value which is 2286.67 kg/m^3. According to British Standard BS-EN-12390 part 7 (2019), The range of normal concrete density is 2300 kg/m^3 to 2400 kg/m^3. Thus, it can conclude that, only 1.00 % of bamboo fibre in concrete achieved the normal concrete density while other percentage not achieved.

4.3 Water Absorption

Water absorption test had been conducted after cured in water tank. This test was conducted to compare between plain concrete and concrete that containing bamboo fibre. The procedure of this test was followed to BS 1881-122:2011. The result of water absorption sample with different percentage of bamboo fibre were recorded in Table 6.

Table 6: Result water absorption test for cube

Mix Proportion of Bamboo Fibre (%)	Water Absorption (%)
0%	2.56
0.5%	2.80
1%	3.80
1.5%	4.14

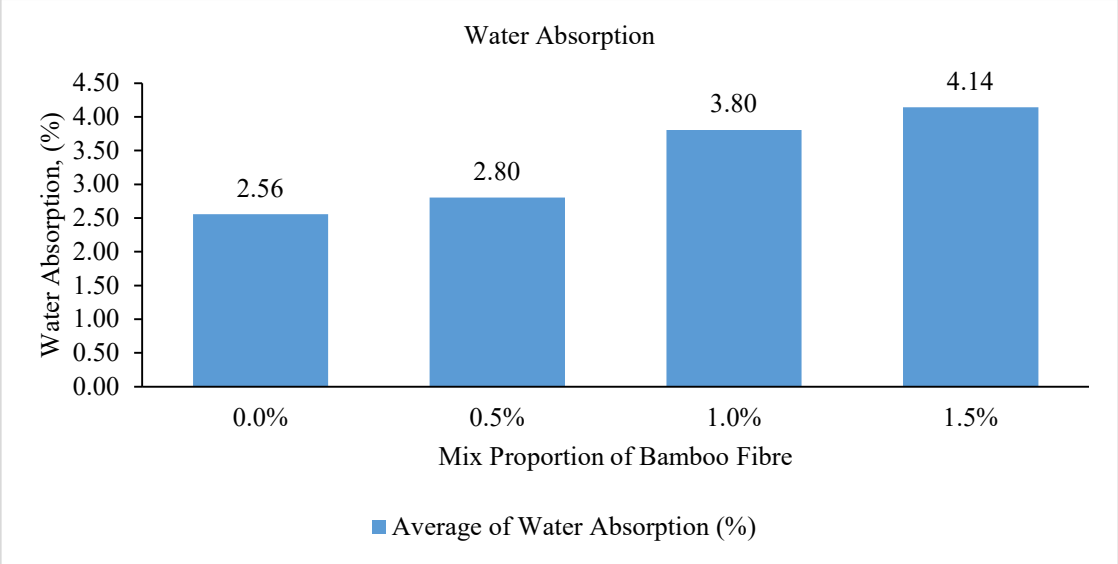

Figure 6: Water absorption versus Mix proportion of bamboo fibre

Based on the observation Figure 6 above, water absorption of cube specimen shows a trend increasing while the mix proportion of bamboo fibre increasing. It is because of the properties of bamboo fibre that absorb water. According to the graph, the value water absorption for 1.50 % of bamboo fibre in 28 days is the highest value which is 4.14 % water absorb in concrete cube. Furthermore, the lowest water absorb is 0.00 % of bamboo fibre used in concrete which is 2.56 % water absorb only. It can conclude that, the uses of bamboo fibre in concrete will increase the water absorb. Thus, will affect the concrete strength.

4.4 Compressive Strength

Result of compressive strength test was obtained by performed 3 specimen cubes for each percentage with size 100 mm x 100 mm x 100 mm for 7 and 28 days. It helps to reduce, minimize error and increase accuracy of result obtain. Table 7 shows the result of compressive strength for 7 and 28 days.

Table 7: Result 7 and 28 days compressive strength test for cube

Mix Proportion of Bamboo Fibre (%)	Compressive Strength for 7 days (N/mm^2)	Compressive Strength for 28 days (N/mm^2)
0%	22.15	31.95
0.5%	21.30	21.54
1%	22.84	20.19
1.5%	23.23	20.94

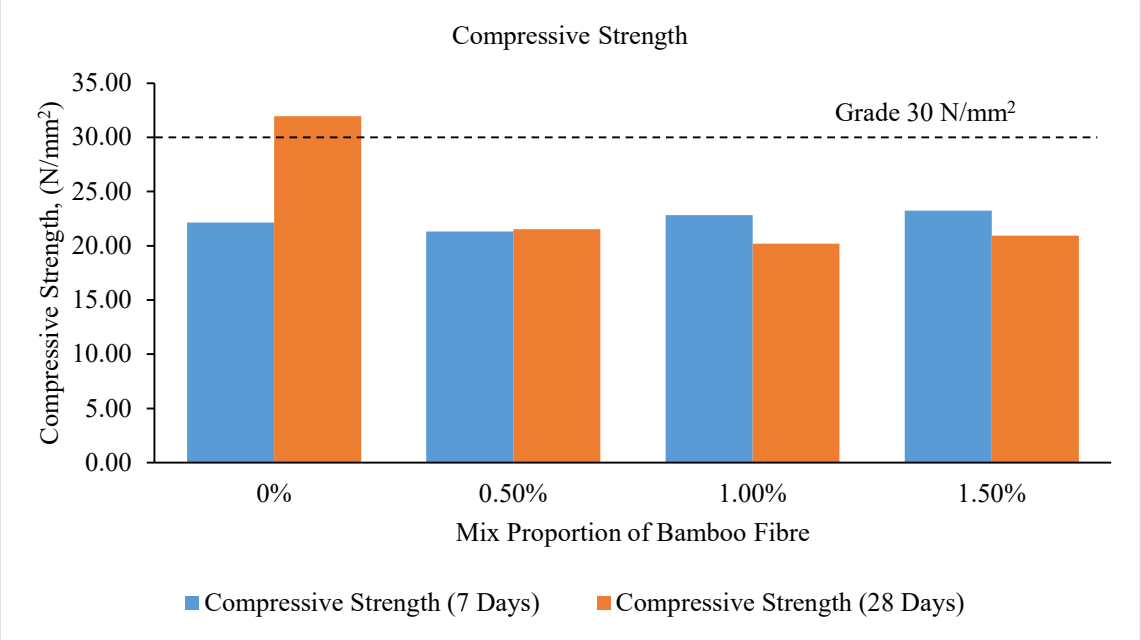

Figure 7: Compressive strength versus Mix proportion of bamboo fibre

According to Figure 7 above, the result of plain concrete for 28 days which is 0.00 % of bamboo fibre was observed as the highest value of compressive strength compare to another concrete that containing of bamboo fibre in concrete. Not only that, plain concrete of 28 days achieved strength 31.95 N/mm^2 which is more that strength grade 30. Besides that, other concrete which containing of bamboo fibre was not achieve the strength target. Furthermore, result for 28 days of 0.50 %, 1.00 % and 1.50 % containing of bamboo fibre in concrete are 21.54 N/mm^2, 20.19 N/mm^2 and 20.94 N/mm^2 respectively. The result of 7 days of concrete that containing of bamboo fibre almost similar with result of 28 days. This is because of the slump of 0.50 %, 1.00 % and 1.50 % of bamboo fibre was not achieve the slump target which is 30 mm to 60 mm. By addition of bamboo fibre in concrete cause of the strength decreasing. It can conclude that, the compressive strength is affected due to the slump result.

4.5 Split Tensile Strength

Split tensile strength test was performed to indirect tension for concrete. This test was carried out by using cylinder specimen. The size of cylinder that was used is 150mm diameter and 300mm height. Each percentage of bamboo fibre have 3 specimens to get the accuracy data for splitting tensile strength. This specimen was cured in water tank within 28 days before performed the splitting tensile strength test. The result was obtained and recorded as Table 8.

Table 8: Result 28 days split tensile strength test for cylinder

Mix Proportion of Bamboo Fibre (%)	Tensile Strength (N/mm^2)
0%	3.09
0.5%	2.68
1%	2.34
1.5%	2.52

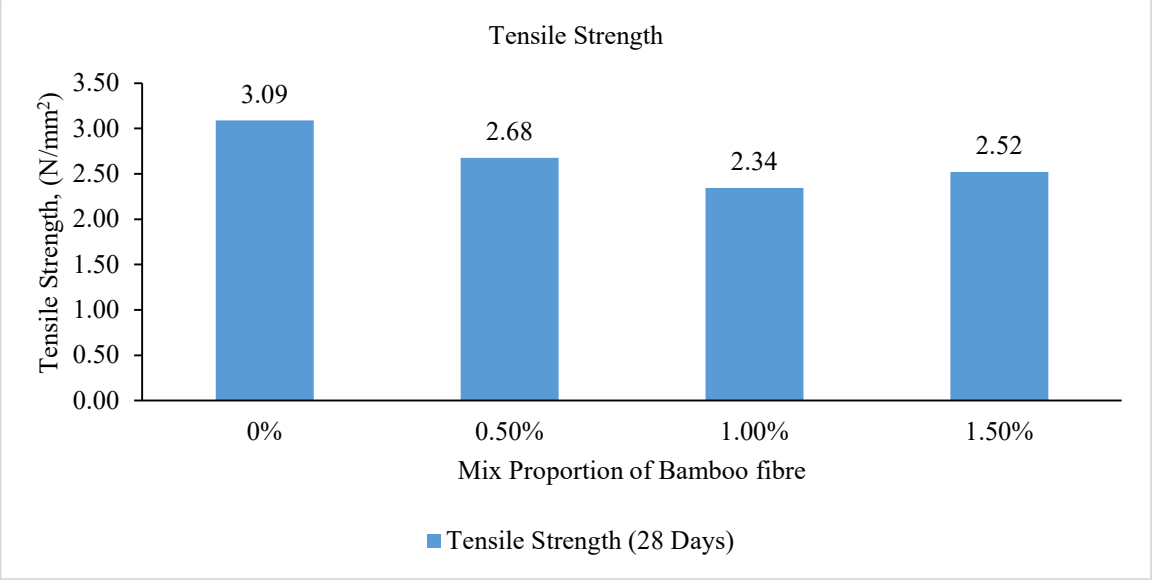

Figure 8: Tensile strength versus Mix proportion of bamboo fibre.

Splitting tensile strength of bamboo fibre reinforced concrete with 1.00 % addition of bamboo fibre as shows in Figure 8 is the lowest value which is 2.34 N/mm^2 compared to the plain concrete achieved the highest value which is 3.09 N/mm^2. Moreover, bamboo fibre reinforced concrete with 0.50 % bamboo fibre had been shown tensile strength decreasing result which is from 3.09 N/mm^2 to 2.68 N/mm^2 when addition 0.50 % of bamboo fibre in concrete. Furthermore, tensile strength of 1.50 % of bamboo fibre was increase from (1.00 %) 2.34 N/mm^2 to (1.50 %) 2.52 N/mm^2. However, the tensile strength of 1.50 % of bamboo fibre in concrete still below the plain concrete of tensile strength which has a different of 0.57 between plain concrete with 1.50 % of bamboo fibre reinforced concrete. Result of splitting tensile strength test with ratio 0.50 %, 1.00 % and 1.50 % were compared with plain concrete had been shows in Fgure 8 above.

4.6 Flexural Strength

Flexural strength test was performed by using three-point load test until the beam failure. The size of beam that was used is 500 mm x 100 mm x 100 mm. This specimen was cured in water tank within 28 days before performed the flexural strength. The result was obtained and recorded as Table 9.

Table 9: Result 28 days flexural strength test for beam

Mix Proportion of Bamboo Fibre (%)	Flexural Strength (N/mm^2) $^{(x10-5)}$
0%	3.38
0.5%	2.88
1%	2.88
1.5%	3.13

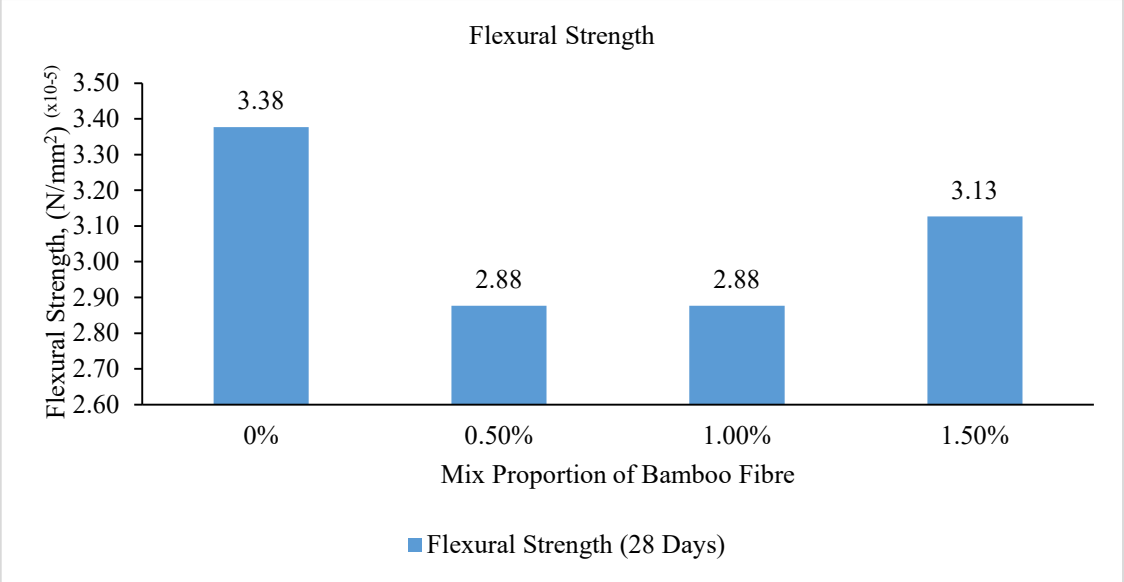

Figure 9: Flexural strength versus Mix proportion of bamboo fibre

Based on the figure 4.6 shows the pattern of flexural strength values for plain concrete and concrete that containing of bamboo fibre in concrete which is 0.50 %, 1.00 % and 1.50 %. The result of flexural strength of 0.00 %, 1.00 % of bamboo fibre was obtained the lowest value which is 2.88 compare to plain concrete that achieved the highest flexural strength which is 3.38. Besides that, result of flexural strength for 1.50 % of bamboo fibre achieve higher than 0.00 % and 1.00 % which is 3.13. Therefore, by addition of bamboo fibre in in concrete are not significant and not affect in flexural strength. This is because bamboo fibre are commonly applied in textile and composite product.

4.7 Ultrasonic Pulse Velocity (UPV)

Ultrasonic pulse velocity (UPV) test was performed by using direct method for measure cylinder n beam specimen. UPV test is one of the methods to determine the quality of the concrete. The size of cylinder and beam that was used is 150 mm diameter x 300 mm height and 500 mm x 100 mm x 100 mm respectively. Each percentage of bamboo fibre have 3 specimens to get the accuracy data for ultrasonic pulse velocity (UPV) test. This specimen was cured in water tank within 28 days before performed the UPV test. The result was obtained and recorded as Table 10.

Table 10: Result 28 days ultrasonic pulse velocity (UPV)

Mix Proportion of Bamboo Fibre (%)	Ultrasonic Pulse Velocity (UPV) for Cylinder (km/s)	Ultrasonic Pulse Velocity (UPV) for beam (km/s)
0%	4.10	4.11
0.5%	3.31	4.08
1%	3.80	4.04
1.5%	3.71	4.00

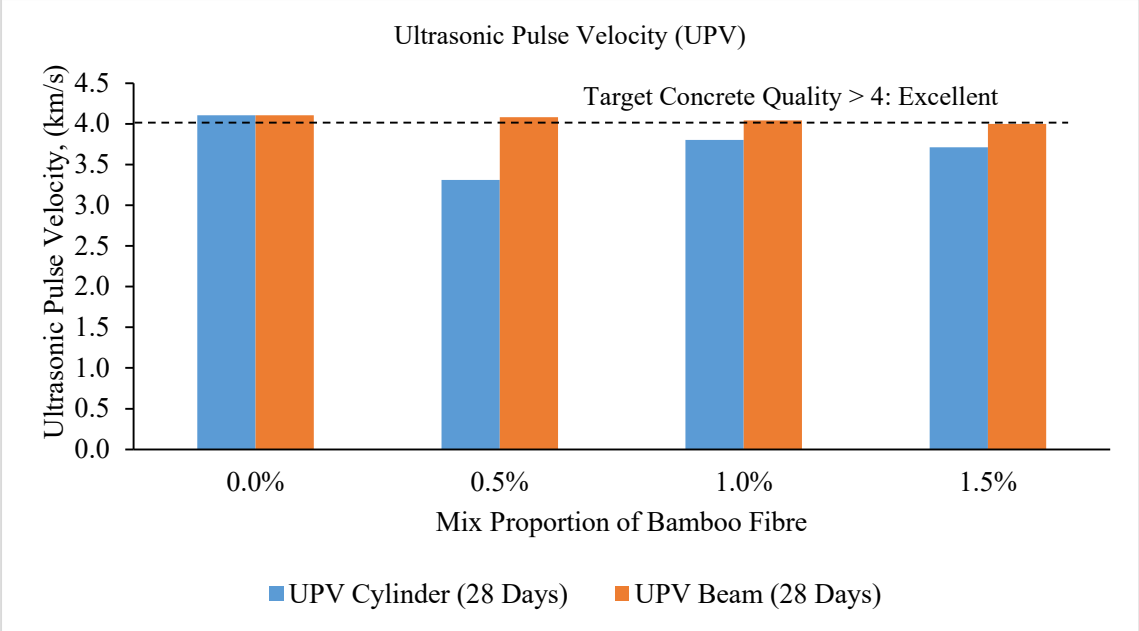

Figure 10: Ultrasonic pulse velocity versus Mix proportion of bamboo fibre.

According to Figure 10 above, direct method was use in this ultrasonic pulse velocity experimental. The result of ultrasonic pulse velocity plain concrete for cylinder and beam achieve almost similar result which is 4.11 km/s and 4.10 km/s respectively in within 28 days cured in water tank. Furthermore, result for 0.50 %, 1.00 % and 1.50 % of bamboo fibre in beam concrete was decreasing due to addition of bamboo fibre. However, all the result ultrasonic pulse velocity for beam concrete achieved the target concrete quality which is 4.0 km/s above. Besides that, there are three-cylinder specimen that not achieve the concrete quality which is 0.50 %, 1.00 % and 1.50 %. It is because of not compact properly and cause of honeycomb at around the cylinder.

5. Conclusion

In a conclusion, bamboo fibre are not suitable used in concrete because of the performance bamboo fibre concrete is lower than the conventional concrete. There are some conclusions that can be conclude based on this study:

i. The characteristics of bamboo fibre that absorb water was affected the slump result and the quality of the concrete.
ii. The addition of bamboo fibre in the concrete reduced the slump of the fresh concrete significantly. As the percentage of bamboo fibre added to the concrete increase, the slump of the concrete reduced. The concrete mix has become tough to handle as a result of this.
iii. The compressive strength, tensile strength and flexural strength result for bamboo fibre reinforced concrete decreased when the percentage of bamboo fibre in concrete increase. Addition 0.50 %, 1.00 % and 1.50 % of bamboo fibre in concrete has decreased the compressive strength, tensile strength and flexural strength. However, plain concrete achieved the highest strength in this three-test compared to another sample. Furthermore, ultrasonic pulse velocity for beam and plain cylinder achieved the excellent result which is greater than 4 km/s except cylinder that obtained good quality for 0.50 %, 1.00 % and 1.50 %.
iv. The addition of bamboo fibre in concrete are not significantly to improve the compressive strength, tensile strength and flexural strength. This is because, bamboo fibre commonly applied and used in textile industry and polymer composite product. Thus, the optimum percentage bamboo fibre in concrete are 0.00 %.
v. In addition, it is found that the result of the strength from some of the previous studies that used approximately the same size as this study, got lower than plain concrete and some of if just got

a little higher than plain concrete. Thus, in this study, 30mm length of bamboo fibre reinforced concrete has been used. However, the outcome of the strength of the bamboo fibre concrete is lower than the plain concrete.

vi. For future study, it is recommended to use the different mix proportions to obtain the most optimum percentage that suitable for bamboo fibre reinforced concrete.

vii. Not only that, by washing the bamboo fibre before mixing in concrete to avoid water absorb and slump not achieve the mix design concrete (DOE) and when uses of superplasticizer in concrete must mix frequently and constantly to avoid hardening on the tray is also recommended.

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